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GERMAN BONFIRE TESTS ON 40MM HE AMMUNITION AND THE UK ANALYSIS OF THE RESULTING DEBRIS DATA INTERIM REPORT

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ABSTRACT

A comprehensive programme of testing and analysis has been completed to determine the explosion effects from the initiation of stacks of 105mm HE Cartridge and 81mm HE Mortar Hazard Division 1.2 ammunition and is reported elsewhere at this Seminar. The German Federal Armed Forces Materiel Office sponsored a series of tests with the aim of extending the database generated from these trials to encompass 40mm HE ammunition. To date a preliminary test and one further test have been completed. On each occasion one pallet (240 rounds) of DM31 40mmx365 HE ammunition has been subjected to a UN Bonfire test. Debris distributions have been determined and video recordings made of the events.

UK ESTC have analyzed the data from the preliminary test to determine the debris related Inhabited Building Distance/Net Explosive Quantity and Fatality Probability/Range relationships. The test and its analysis are reported in this paper along with details of the remaining test programme.

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INTRODUCTION

1. Over the last 5 years a joint UK/US programme of tests has been carried out to determine the effects of the accidental initiation of quantities of 105mm and 81mm calibre Hazard Division 1.2 ammunition. The Federal Armed Forces Materiel Office of the Federal Republic of Germany commissioned a series of tests to extend the range of testing to include 40mm HE ammunition (Reference 1). A pilot test in which a unit load (240 rounds) of Cartridge 40mmx365 DM31 was subjected to a UN bonfire test was carried out in September 1995. The results of the test were published at Reference 2. The reactions commenced about 8 minutes after the bonfire was started and continued for 26 minutes. As rounds exploded individually there was no blast hazard beyond a few metres from the bonfire and the only longer range hazard was that from the fragments and debris. In the paragraphs below the debris and fragmentation data from the preliminary test are analyzed and the results compared with Norwegian data (tests following a transport accident), a large scale US test and recently published US/UK proposals for HD 1.2 quantity distances. Additionally a fatality probability/distance relationship is calculated. Initial analysis of the test carried out in January 1996 indicates that the results are very similar to those of the preliminary test excepting that the first event occurred after only three minutes and two cartridges were thrown in excess of 220m (no debris was found beyond 150m in the preliminary test).

ANALYSIS METHOD

2. The selection of debris as "lethal" was more difficult in these tests than in tests of larger calibre ammunition. At longer ranges, a mixture of cartridge cases, projectile pieces and debris are found rather than the heavy projectile pieces found with the larger calibers. Examination of this mixed debris indicates that some may be wind blown or "float" from the bonfire as it is of large area, eg ammunition box sides. In the following analysis a worst case condition is used in which <u>all</u> debris and fragments are counted as lethal. In future tests, it is intended that carefully designed area/mass/material criteria will be developed to assist in differentiating between potentially lethal and non-lethal debris or fragments.

3. A second initial assumption was made that there was no directional dependence in the debris and fragment throw. Fragments were counted within annular zones and their numbers recorded as a function of mean zone radius. As fragments arriving in an outer zone will have passed through those within it, they are considered to contribute to the fragment densities of all zones they pass through. This "trajectory normal" approach (Reference 3) is of course conservative as it takes no account of the height at which the fragments pass through the zones. In practical terms the numbers of fragments are simply added accumulatively from the outermost inwards.

4. The fragment density per 55.7m^2 is then calculated for each annulus. The

Inhabited Building Distance (IBD) for the stack of 240 rounds can then be identified as the range at which the density per 55.7m^2 becomes unity. This curve is plotted at Figure 1. In addition to the experimental points, a cubic curve fit is shown. Its equation is:

$$\text{Density}/55.7m^2 = -6.816806E\text{-}6*R^3 + 1.893511E\text{-}3*R^2 - 0.1892353*R + 5.253828$$

where R is the range in metres.

5. To determine the IBD for other quantities of rounds or, if converted, Net Explosives Quantities (NEQ), the assumption is made that the density of fragments at any given range is proportional to the number of rounds in the stack. Thus, by calculating the density/range figures for one round and then multiplying up to different stack sizes the point at which the density becomes unity can be measured or calculated by solving the above equation suitably modified for each quantity considered (the difference lies only in the size of the constant). Figure 2 shows the variation of IBD with NEQ calculated from the German test data.

6. The expected number of hits, NE_H on a human target (assumed area 0.56m^2) is given by

$$NE_H = 0.56 \times \text{Debris Density}$$

then from Poisson statistics the chance of at least one hit as a function of range can be calculated as

$$P_H = EXP(1-NE_H)$$

Given that the consequence of being hit by at least one fragment is fatality, then this becomes a fatality probability vs range relationship. This is shown in Figure 3 for the German preliminary test.

COMPARISON WITH US AND NORWEGIAN DATA

7. In July 1975 the US Department of Defence Explosives Safety Board (DDESB) funded a test programme to provide fragmentation data for HD 1.2 ammunition. One item in the programme was the US Navy 40mm AA Cartridge. Far field fragment collection was carried out in tests in which stacks of 4, 8, 9, 18 and 36 pallets were subjected to bonfire tests. They state (Reference 4) that "debris (cartridge cases, containers etc) was primarily contained within 500ft of the test site. Fragments recovered at 1400ft." More recently this and data on other calibers of ammunition have been analyzed (Reference 5) in a similar fashion to that used here to produce a family of IBD vs NEQ curves for different NEQ ranges. The curve for the lowest NEQ range (CATEGORY 1, NEQ<=0.24lb) is based on the US 40mm data and can be

FIGURE 1 LOG10 (DENSITY/55.7M^2) VS RANGE
FOR GERMAN PRELIMIINARY 40MM HE BONFIRE TEST

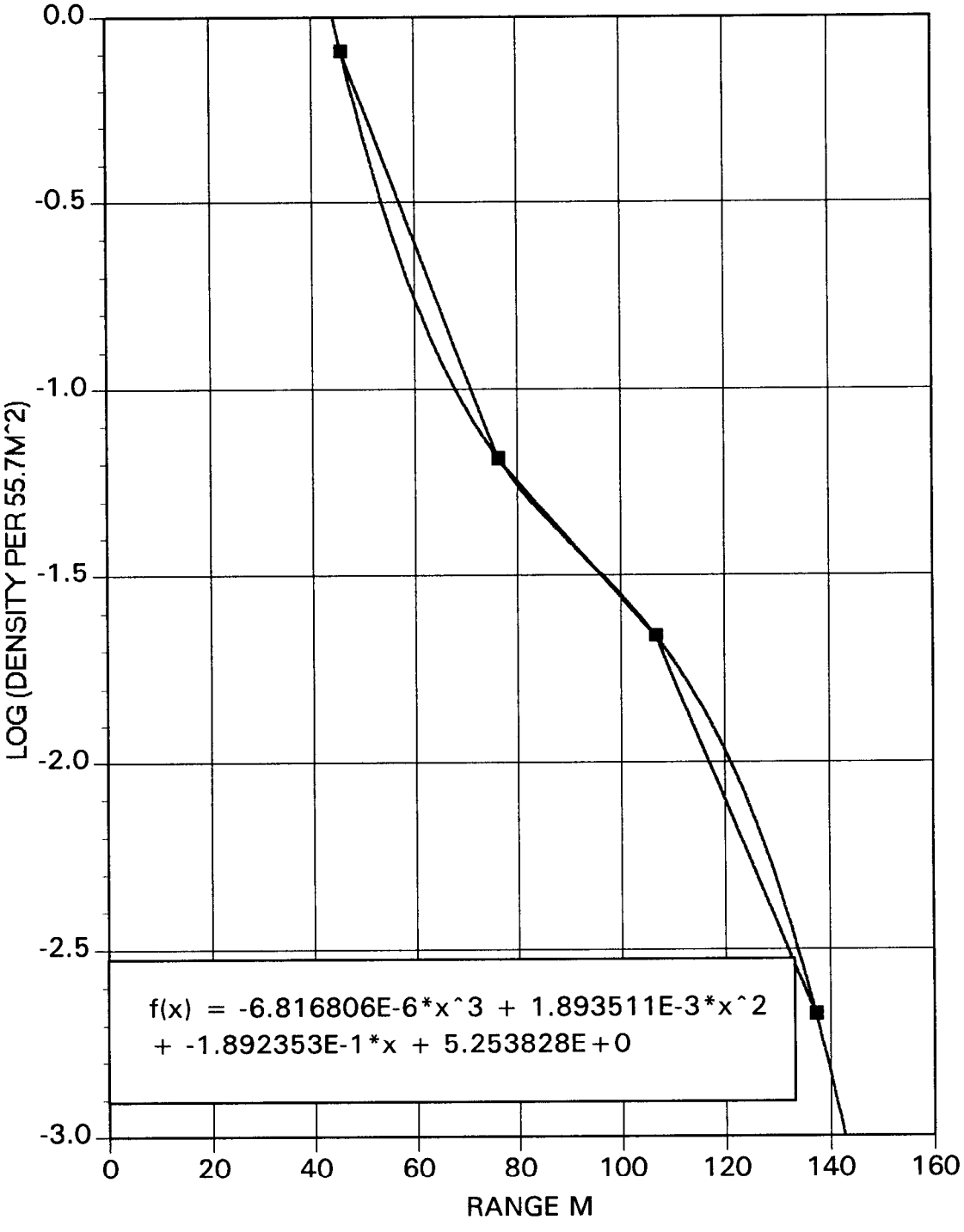


FIGURE 2 IBD AS A FUNCTION OF NEQ FROM THE GERMAN PRELIMINARY TEST DATA (NEQ/ROUND = 0.597kg)

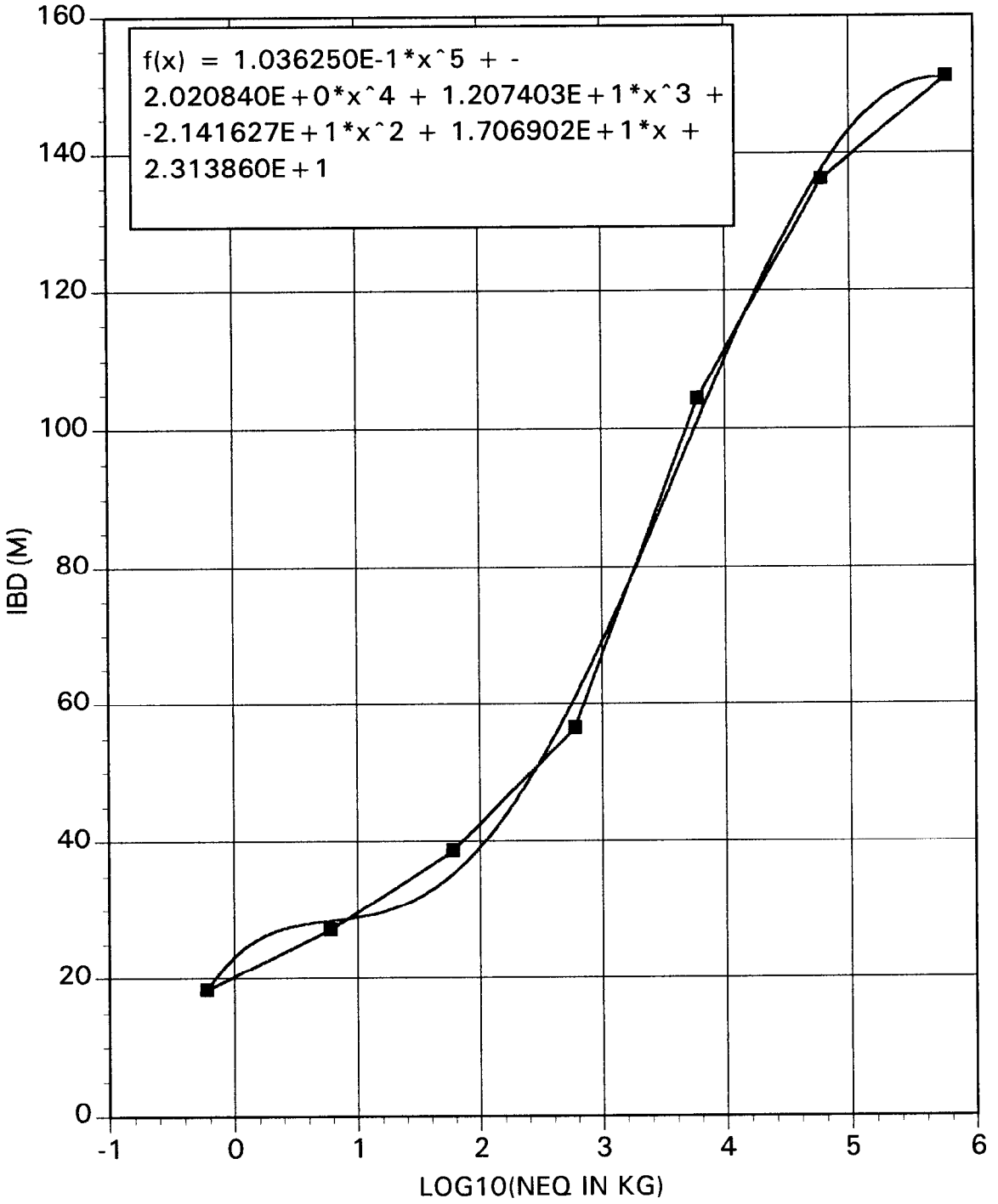
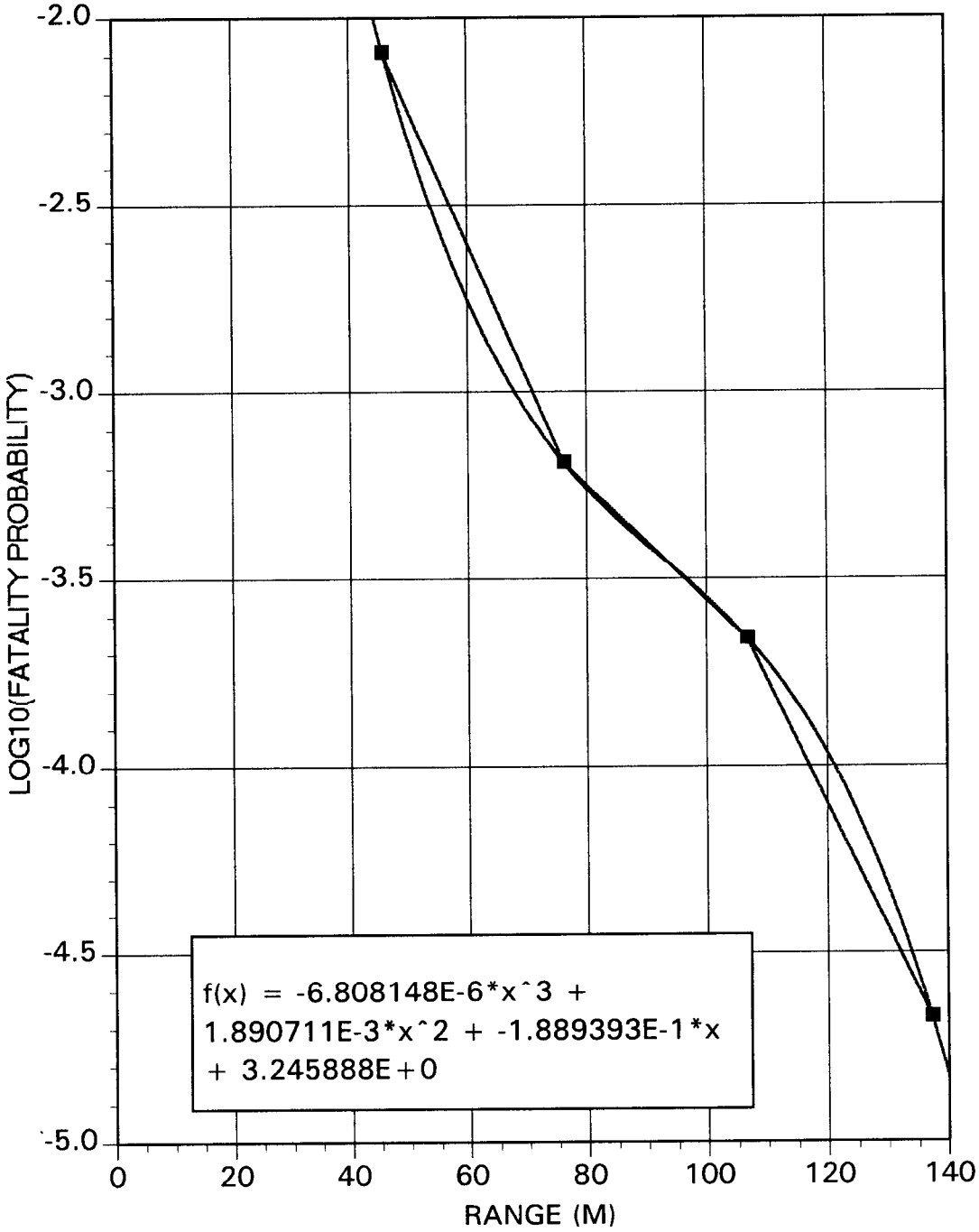


FIGURE 3 LOG10(FATALITY PROBABILITY) VS DISTANCE FOR GERMAN 40MM PRELIMINARY TEST



compared with the German data given the appropriate choice of NEQ. The NEQ used in Reference 4 is that for the warhead only rather than the total NEQ including propellant usually used. If this total NEQ were to be used then the curve for the next NEQ range (CATEGORY 2, 0.24lbs<NEQ<2.65lbs) would become pertinent although it is not based on 40mm data. The German and both US curves are compared in Figure 4 along with those for the Norwegian tests described below.

8. In May 1985 a semi-trailer loaded with 40mm HET ammunition for the L60 AA gun caught fire as the result of a burst tyre (Reference 6). There were 2304 rounds on the trailer on 16 pallets. They were packed 6 to a wooden box and 24 boxes per pallet.The first round was heard to react 25 minutes after the fire started and rounds continued to explode for a further 85 minutes. Most rounds were found within 70 to 100m 0f the explosion site. Thorough searches, both visual and with metal detectors failed to find 214 rounds and these were presumed to have fully detonated and produced fine fragments too small to detect.

9. As a result of the accident, Norway carried out a controlled bonfire test to simulate the accident in order that the effect of steel packaging compared with wooden packaging could be examined (Reference 6). Five metal cases of 16 rounds each were used in the first test and 5 wooden boxes of 6 rounds each in the second. The conclusions drawn were that there was little difference between the fragment throw from the two packaging arrangements. The pickup data from these two tests has been analyzed in the same way as above. In the absence of NEQ information for the round, the same value as that of the DM31 rounds used in the German test was assumed, to enable comparable quantity/distance relationships to be calculated. The resulting comparison is shown in Figure 4.

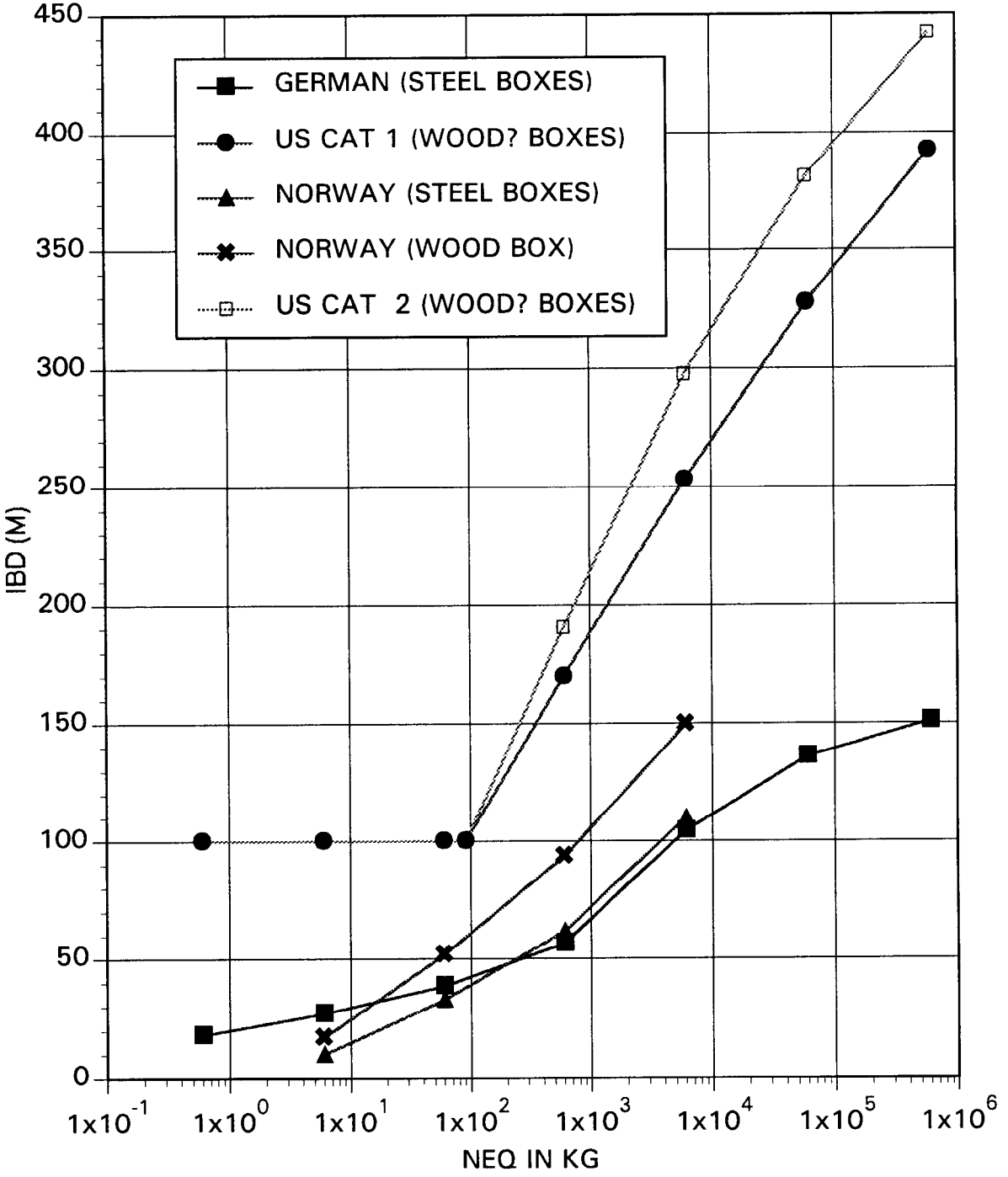
DISCUSSION

10. There is a clear discrepancy between the US curves and the others in that the US predicted IBD is always significantly larger than either the German or Norwegian predictions. Considering the similarity in the natures of ammunition tested, this difference would not be expected; that shown between the two Norwegian and the German data seeming more credible. The US are currently investigating their 40mm test data and further information is being sought on the exact ammunition design used in the US and Norwegian tests in order that it can be compared with that for the DM31 round.

11. The data for the German test and the Norwegian test in steel boxes show a remarkable similarity. The slightly worse case exhibited by the Norwegian test in which the ammunition was packaged in wooden cases may reflect greater containment of the exploding ammunition by metal boxes. However tests to produce sufficient data to develop greater statistical reliability would have to be carried out to prove the point.

CONCLUSION

FIGURE 4 COMPARISON BETWEEN US, NORWEGIAN AND GERMAN IBD DATA FOR 40MM HD 1.2 ROUNDS



12. The results of bonfire tests on 40mm HE ammunition in Germany and Norway have predicted shorter Inhabited Building Distances than similar tests in the United States. The reasons for this are still being investigated.

13. Further testing is necessary to determine more exactly the relationship between explosives quantities and fragment hazard for small calibre HD 1.2 ammunition.

FUTURE TEST PROGRAMME

14. Three further exposed site tests are to be carried out at the Meppen Ranges as follows:

1 pallet test	**Week of 9 September**
2 pallet test	**Week of 1 November**
8 pallet test	**Week of 2 December**

In addition a test within a structure is planned for January/February 1996

REFERENCES

1. **Federal Armed Forces Materiel Office MatABw-IV 1-AC/258 GE(ST)IWP 2-95 dated 17 March 1995**

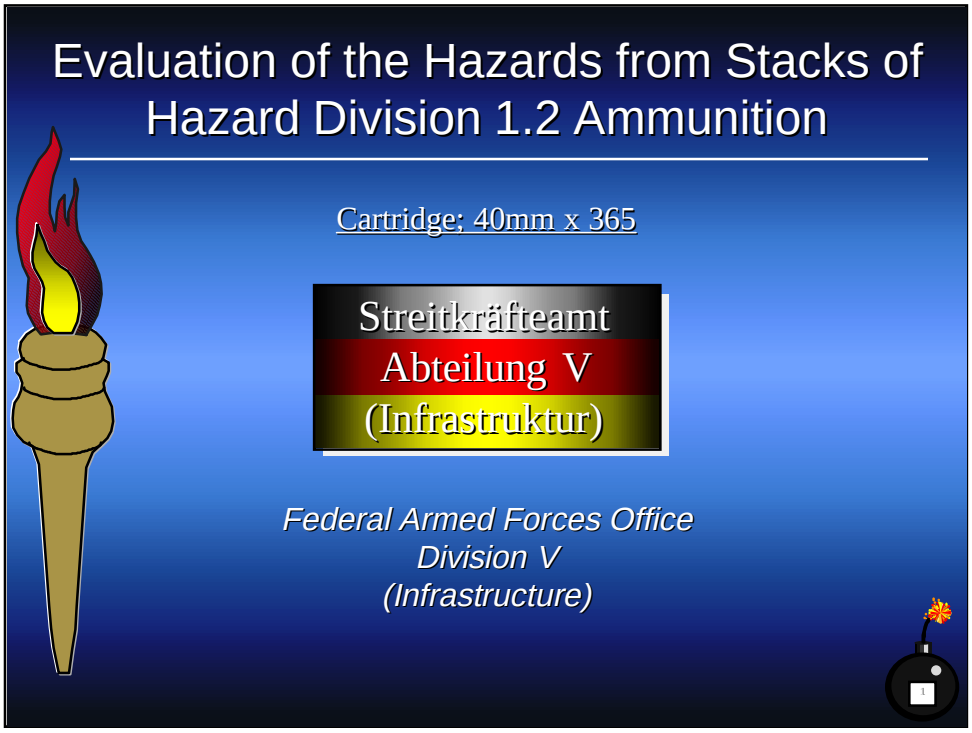
2. **Federal Armed Forces Materiel Office MatABw-IV 1-AC/258 GE(ST)IWP 1-96 dated 16 January 1996.**

3. **Procedures for the Analysis of the Debris Produced by Explosion Events, M M Swisdak, Paper to 24th DoD Explosives Safety Seminar, August 1990**

4. **Fragment Hazard Investigation Program Non-mass Detonating Ammunition Tests, W D Smith, Minutes of the Twentieth DoD Explosives Safety Seminar, August 1982.**

5. **Hazard Division 1.2 Effects from Open Stacks, M M Swisdak, W D Houchins, J M Ward and M J A Gould, Proceedings of the 2nd PARARI Conference, Australia, October 1995.**

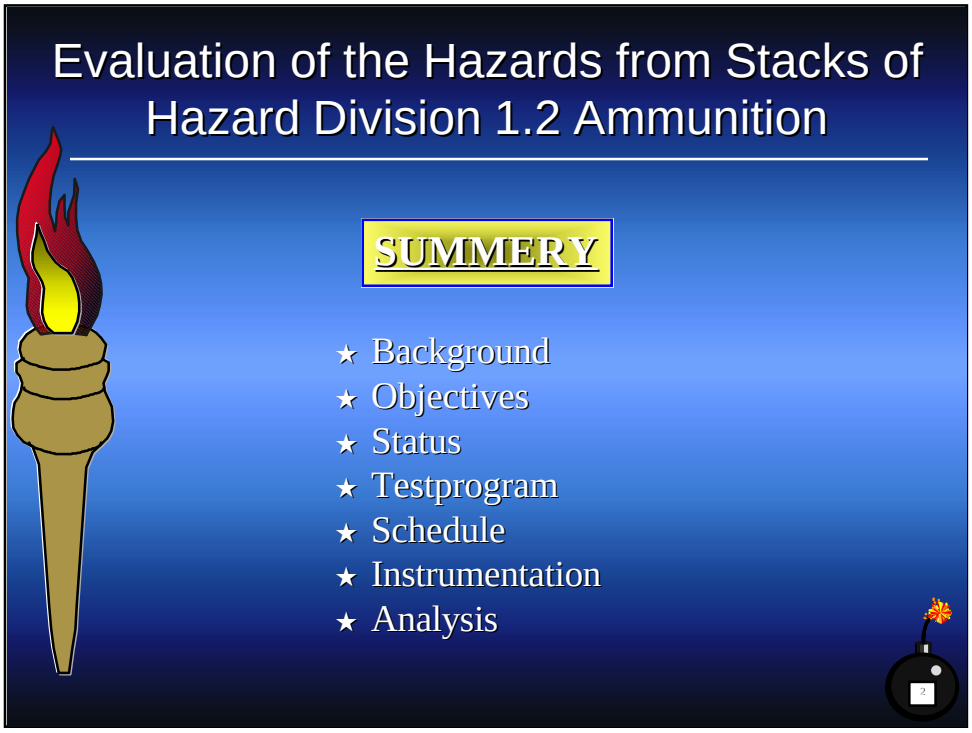
6. **Information on the Fire of 14 May 1985 in Norway in a Semi-trailer Loaded with 40mm HE-T Ammunition, Report from an External Stack Fire Test, AC/258-NO(MG)IWP 80 dated 24 April 1986.**



Ladies and Gentlemen,

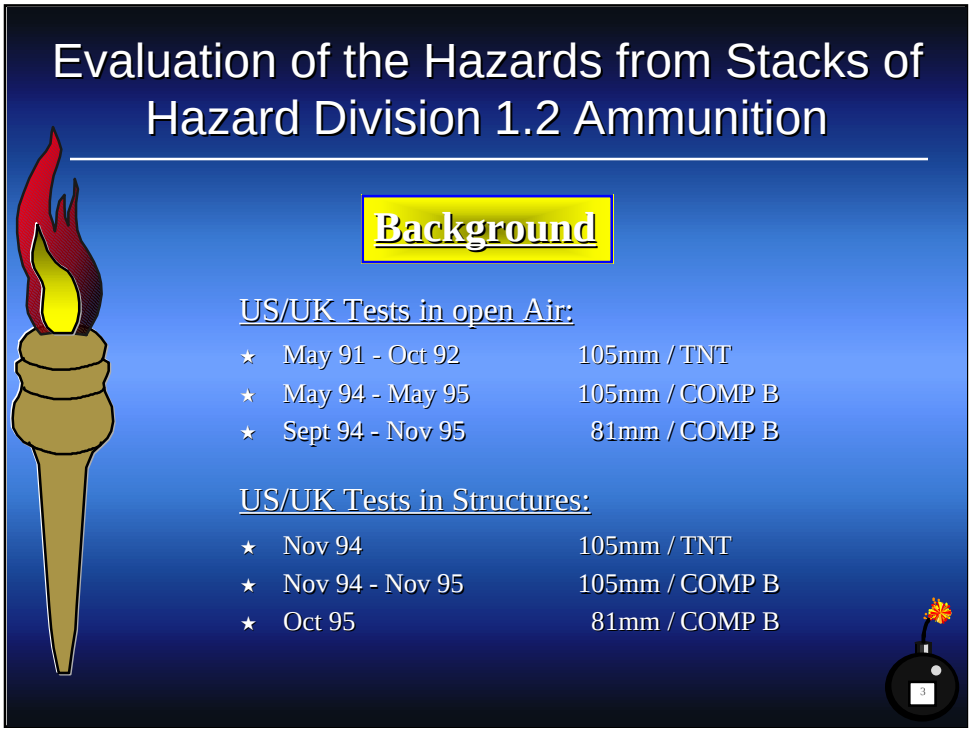
This briefing will present the German contribution to the program of testing stacks of Hazard Division 1.2 ammunition.

I have structured my briefing as follows:



In order of time, I will only pick out the major points of the whole briefing.

The Analysis will be presented by Mr Gould.



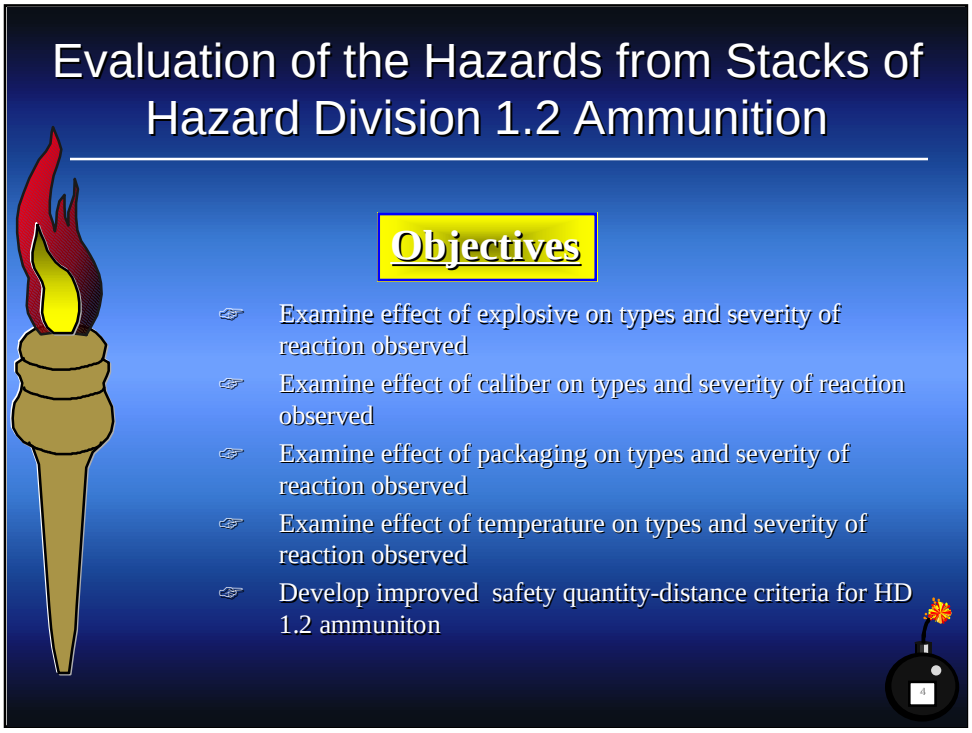
This program started in 1991 when the United States Department of Defense Explosives Safety Board (DDESB) in conjunction with the United Kingdom Explosives Storage and Transportation Committee (ESTC) have begun with test on the **TNT** loaded and later on **Composition-B** loaded 105 mm and mortar 81 mm cartridges.

The status of the program can be seen on this chart.

The overall objective of this program is to

- Develop improved tests and analysis procedures for hazards of open stacks of HD 1.2 ammunition
- Develop improved safety quantity-distance criteria for HD 1.2 ammuniton
- Compare test results with available data

In all tests, the rounds reacted one at a time - somewhat like popcorn, with the first reaction approx. 20 minutes after start of the fire, and the final reaction approx. 60 minutes later.



The main objectives of these tests are:

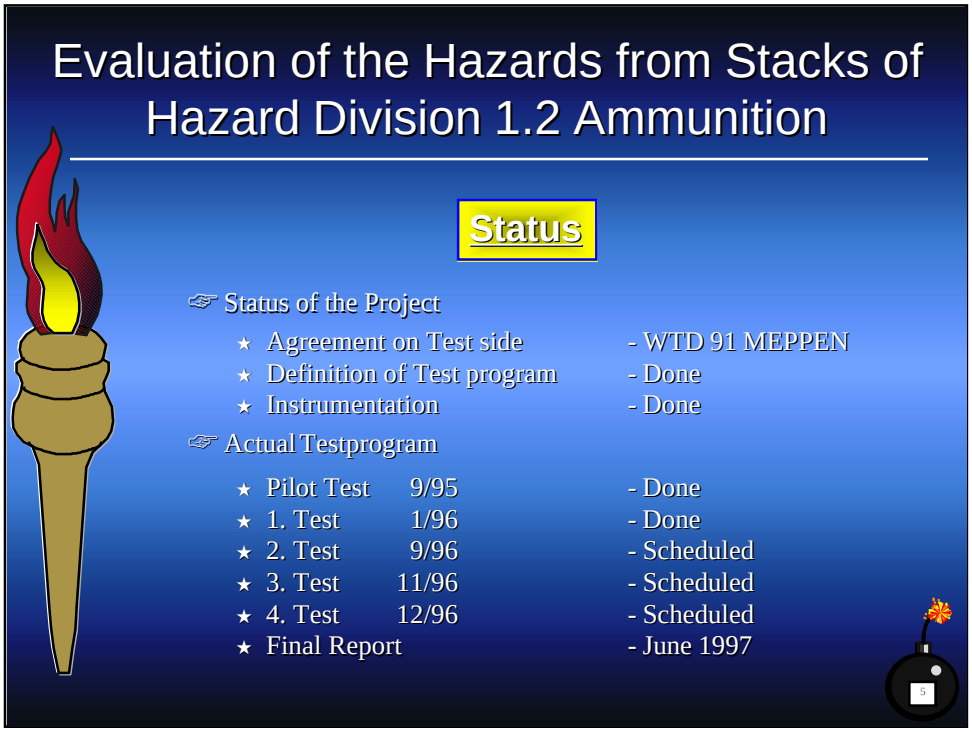
- Examine effect of explosive on types and severity of reaction observed
- Examine effect of caliber on types and severity of reaction observed
- Examine effect of packaging on types and severity of reaction observed
- Examine effect of temperature on types and severity of reaction observed
- Develop improved safety quantity-distance criteria for HD 1.2 ammuniton

For our test series we have selected the

Cartridge 40 mm x 365 DM 31 / DM 81

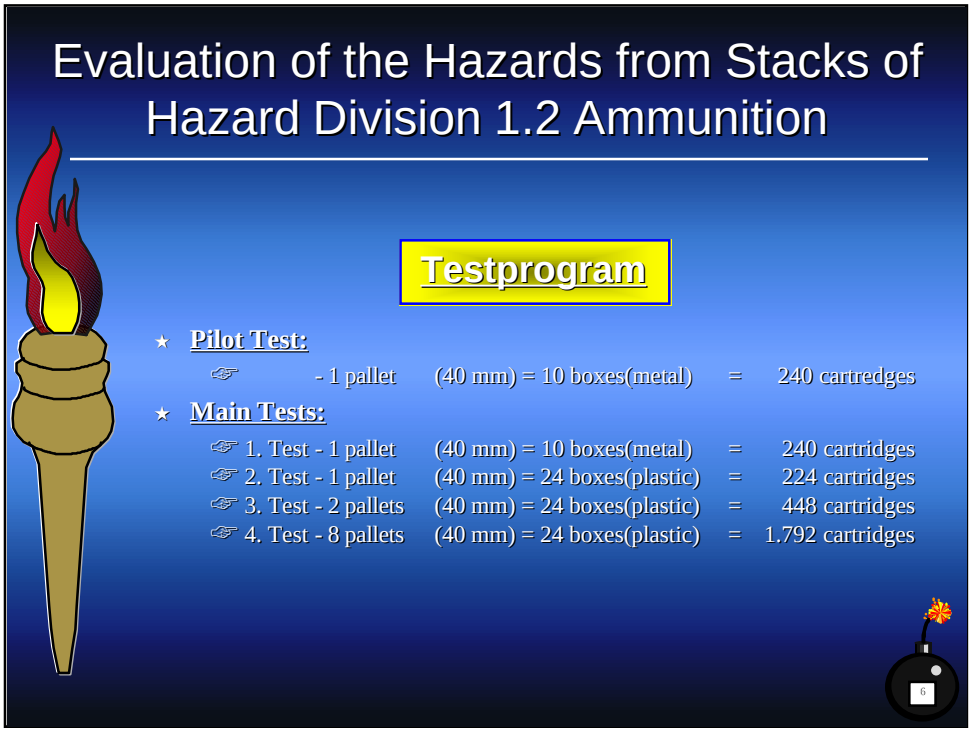
in either steel and plastic boxes.

The NEQ-Equivalent of one Cartrige is about 600g .



A total of 5 tests are planned.

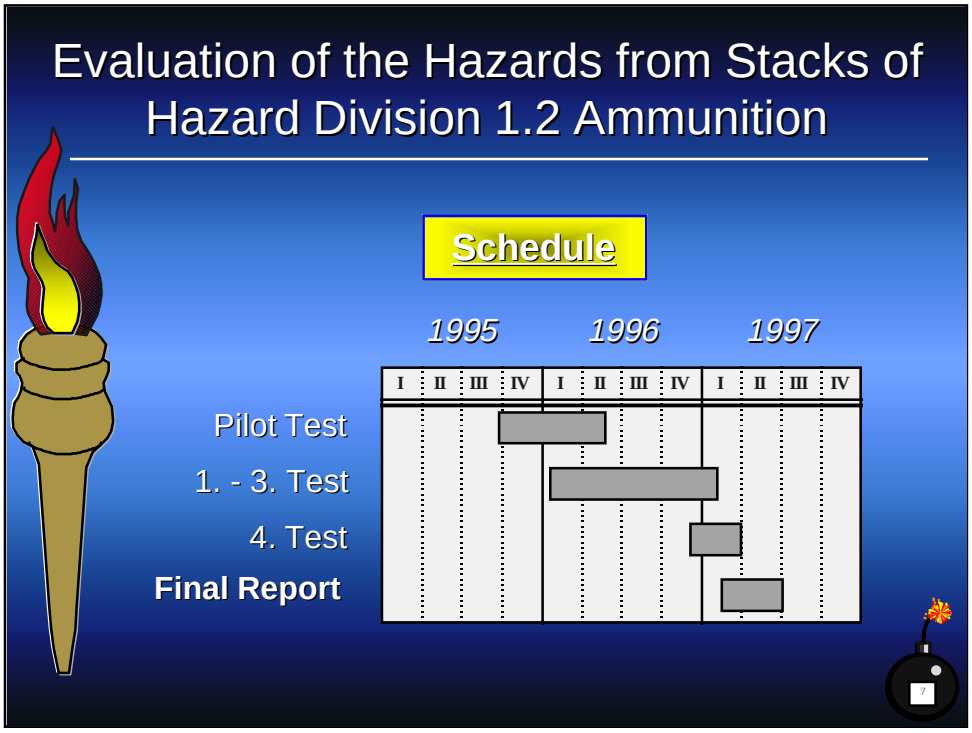
The status is as listed.



On this viewgraph You can see the overview of how the tests will be conducted.

The objective of the pilot test was to gather fragmentation range data which were then used to determine the area to be searched in the following tests. No comprehensive instrumentation was used, just Video Cameras.

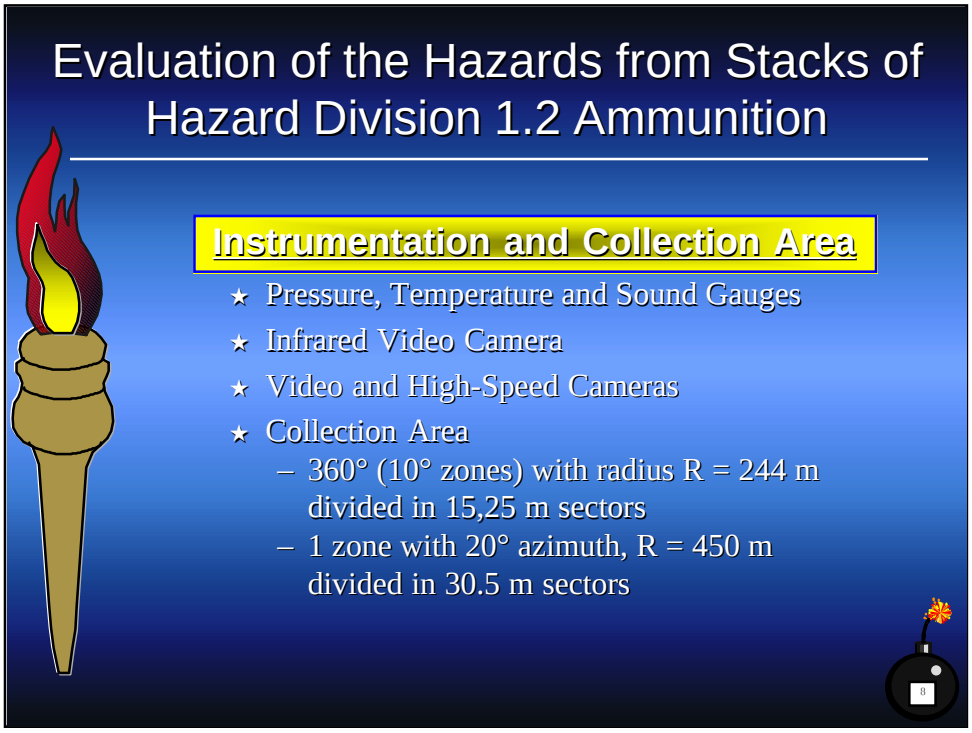
The results of each test will be taken into consideration for the following ones.



On this viewgraph, You can see the planned schedule for the tests.

This schedule includes the

Fragment Recovery
Data Analysis
Data Report Preparation
Test Site Preparation and
Instrumentation Checkout.



Each test will be recorded in real time on video.

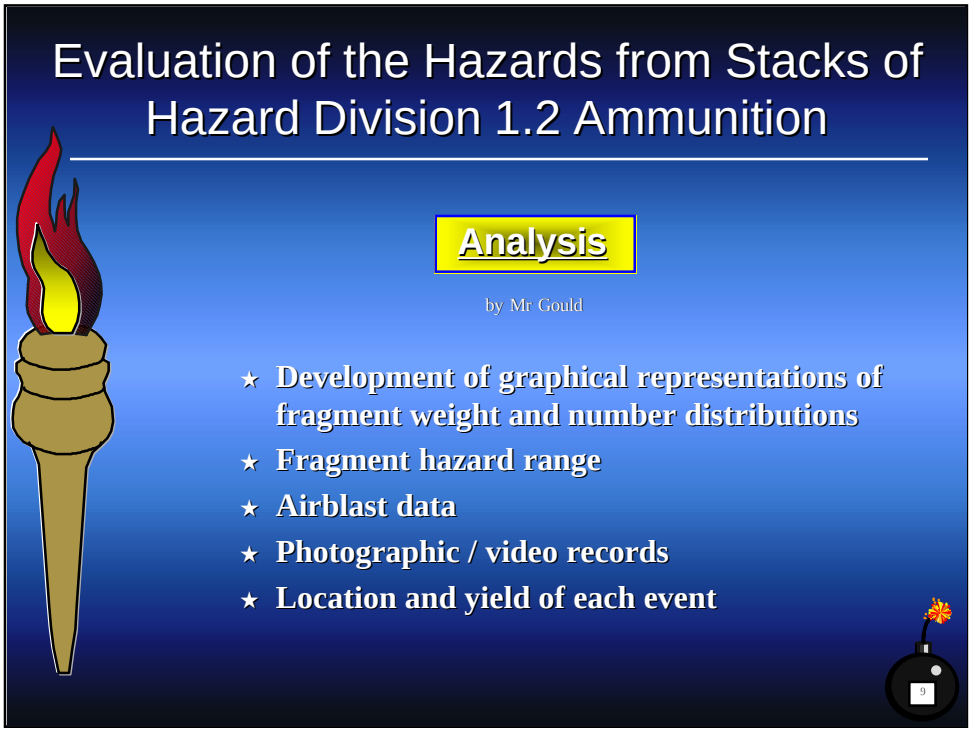
Two high-speed cameras (400 pics/s) will be used.

Thermocouples will be placed inside the cartridge, outside the cartridge and on the exterior walls of pallets to record flame temperatures.

Pressure gauges will be placed along three radial lines to record any airblast on each explosion.

The Fragment Collection Area will be 360° with an overall radius of 244m, A Sector of 20° Azimuth, devided in 30,5m will be researched up to the total lenght of 457,5m.

Upon completion of all tests, a final report will be made available to all participants.



Before Mr. Gould will present the Analysis some major points.

Pilot Test:

First reaction after about 8 minutes
Duration about 26 minutes
6 projectiles detonated
Fragments in the internal circle 95% (r=30,5m), therefor reducing the internal circle to r=15,25m.
The maximum range of a fragment amounted to about 150m (1 fragments with a mass of 740g).

1. Test:

First reaction after about 4 minutes
Duration about 30 minutes
9 projectiles detonated
Fragments in the internal circle 76% (r=15,25m).
The maximum range of a fragment amounted to about 225m (2 fragments were found at a range of 220m with a mass of 740g and 152,5m with a mass of 750g).
1 Detonation was recorded 19m away from the center.

We start to prepare the tests inside structers and hope to conduct the pilot test at the end of January 1997.

This concludes my part of the briefing.